Monthly Progress Report

P-B1980-7

HERO SUPPORTING STUDIES

by

Norman P. Faunce
Paul F. Mohrbach

January 1 to January 31, 1963

Prepared for

U. S. NAVAL WEAPONS LABORATORY
Dahlgren, Virginia

Contract No. N178-8102

THE FRANKLIN INSTITUTE

LABORATORIES FOR RESEARCH AND DEVELOPMENT

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ABSTRACT

Two Low Band-Pass Transformers (LBT's) were found to have more than 40 db loss at 30 and 250 Mc, when terminated in one ohm. Data show that this loss can be reduced to as little as 15 db if the continuity of the shield from input to output is broken. Temperature rise did not exceed 85°C with 10 watts for one unit, and 125°C with 12 watts for the other.

Repeated tests to confirm the validity of the voltage min-max measurement method are again positive, but the presence of an unaccountable loss adds some confusion. It is conjectured that the power level measured at various points in the system should show a gradual, almost linear, decrease from system input to termination. Data obtained indicates a severe reduction in power level at the front end of the system, but decreasing as expected from thereon. A modification of the basic technique required to offset interference present during these tests does not appear accountable. More critical examination of certain areas is indicated. An exceptionally lossy stub tuner is suspected to be responsible.

SUMMARY

Work on the prototype LBT's has been concluded during this period. Evaluation of their power losses with a one-ohm termination has been completed at 30 and 250 Mc. At the same time, the firing system to be used for the protected MARK 7 MOD 0 ignition elements at these frequencies has been calibrated.

Both transformers give evidence of terminated loss in excess of 40 db, as required. Likewise, each can be shown to have considerably less loss (as little as 15 db) when the shield is not continuous from input to output.

Temperature rise was measured for one unit (#57) with 10 watts input and the other (#58A) with 12 watts at 250 Mc. In the first case, the maximum temperature reached is 85°C; for the higher power test a maximum of 125°C, was reached. This later is higher than the 110°C limit indicated by Weston, but does not appear excessive in view of the power level applied.

Attempts were made to assemble equipment to determine the low frequency loss for these units at high power levels. The tuning unit for the kilocycle range of our low frequency-high power generator had been modified so that it could not be used for this purpose. Rather than change the modification a replacement was ordered. Further work on these units will be delayed until direct support is obtained from the developer, Weston Instruments.

Tests have been scheduled for evaluating a special tantalum capacitor. We ordered and finally received 10 units, which have been prepared for measurements. Data should be ready next period. In succeeding tests, the units will be reevaluated in an arrangement which separates the outer case of the capacitor from the coax system outer conductor by a salt water medium. Design of this special mount is in process.

Efforts to confirm the voltage min-max power measuring technique have been continued. These recent experiments using the HERO transmitter resulted in a deluge of problems. The most significant difficulty was the presence of radiation, well below the human toleration level, but more than enough to introduce serious error into the sensitive measuring equipment. This problem was initially circumvented by resorting to a measurement technique employing two different probe penetrations, one for the maximum and one for the minimum. A major contributor to the source of unwanted radiation was found later, and remedial action initiated.

The outcome of the investigation was much the same as observed previously; a high loss element appears to be located in the front end of the system. The data appears to substantiate our hypothesis that by use of this technique we can measure power flow past a point in an RF system, but we cannot show that this power is directly correlated to the system input power. Additional work is therefore required to track down the cause for the high loss which thwarts our attempts to obtain unquestionable validation.

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1. COMPONENT TESTING

Protected MARK 7 MOD 0 ignition elements are scheduled to be fired at 30 and 250 Mc. The technique used to calibrate these firing systems requires that impedance measurements be made on a number of units. Combining these data with several voltage probe readings the power delivered to the squib termination can be determined. The system calibration factor is the ratio of the system power to this base power. Although the calibration data for the MARK 7 MOD 0 elements is now available, it will be presented in next month's report together with the final results from the functioning test which will be completed then.

At the same time the MARK 7 calibration was being made, measurements of terminated power loss were made for the prototype LBT's. The same impedance-voltage probe technique was required for these determinations; hence they were added to the schedule and given first priority.

One additional component, the tantalum capacitor, has been under study to determine its potential contribution to high frequency attenuation. A sample of ten of these capacitors has been prepared for evaluation.

1.1 Evaluation of Prototype Low Band Pass Transformers

Last month we began to investigate the characteristics of two low band pass transformers (LBT) which were developed by Weston Instruments under contract with the Naval Weapons Laboratory. The intent of tests, agreed to by all parties was first to determine if these models showed promise of fulfilling the minimum standards imposed; and if both were acceptable then to decide which was the better choice for final design. Before the period covered by this report, we had finished low power low frequency (under 1 Mc) power loss measurements and had begun tests at high power; and also determination of loss and temperature rise was completed at 1 and 10 Gc. During the early part of this period we completed the work to be done on these units. Additional evaluations of production models will be performed under contract directly with Weston.

1.1.1 Method for Determining Terminated Power Loss at Intermediate Frequencies (10 to 500 Mc)

The requirement that terminated power loss be determined, if possible, with high power (about 10 watts) presented a challenging problem. Heretofore, our evaluation of loss had been confined to low power systems. Fortunately, we had been developing techniques for measuring input power of any magnitude delivered to an arbitrary termination. Hence for this task we merely had to adapt these new techniques.

In the frequency range of 10 to 500 Mc we use a voltage-impedance technique for measuring power. Knowing the voltage (V) across the input terminals of a device (or a very short distance removed) and the impedance (Z) at the same reference position we may compute power by the formula

$$P = |V|^2 \text{ Re } \left|\frac{1}{Z}\right|$$

For measurements on the LBT's we applied this technique to determine both the power input to the device and the power delivered to the termination or load. An especially designed one-ohm load was constructed for tests of these units, and analysis indicated that it was unaffected by the voltmeter shunted across it while making the measurements at both 29 and 250 Mc.

1.1.2 Results of Measurements at 250 Mc

As was mentioned in the previous report, the transformers were made up with GR connectors in such a way that the shield could float above the measuring system ground. However, by wrapping the units tightly with copper foil it was possible to complete the shield from input to output. In so doing one lead of both the input and output windings was grounded. These units were evaluated in both configurations.

It was presumed that neither measurement would produce results truly indicative of the loss to be expected from the devices properly deployed, but rather values for loss much less than the true loss figure.

The data, obtained at 250 Mc, are given in Table 1-1. It may be observed that at this frequency the input impedance, and therefore the shunt conductance, is very much affected by the integrity of the shield. Furthermore, the loss is, as should be expected, even more affected by the completeness of the shield. These results serve to indicate the result sought; that both the units have greater than 40 db loss at this frequency. (Similar data was obtained at 30 Mc.)

Table 1-1

ESTIMATED POWER LOSS OF LBT's @ 250 Mc

Item No.	Z (ohms)	G (mhos)	V_p (volts)	V_L (volts)	Estimated Loss (db)
57	33-j5	2.96×10^{-2}	108.8	.38	15(1)
	21-j9.5	3.96×10^{-2}	15.4	.02	45(2)
58	33.7-j60.4	7.06×10^{-3}	15.9	.063	28(1)
	21.75-j61.5	5.16×10^{-3}	13.1	.01	>40(2)

(1) with shield floating.

(2) with shield completed from input to output.

1.1.3 Temperature Rise Determination

At 250 Mc both units were evaluated for the rise in temperature experienced by the primary coil during the application of 10 watts of power. Results are shown in Figure 1-1. It is noted that the curve for transformer #58A was obtained with 12 watts of power instead of the 10 requested. Even with this higher power input temperature rise does not appear excessive.

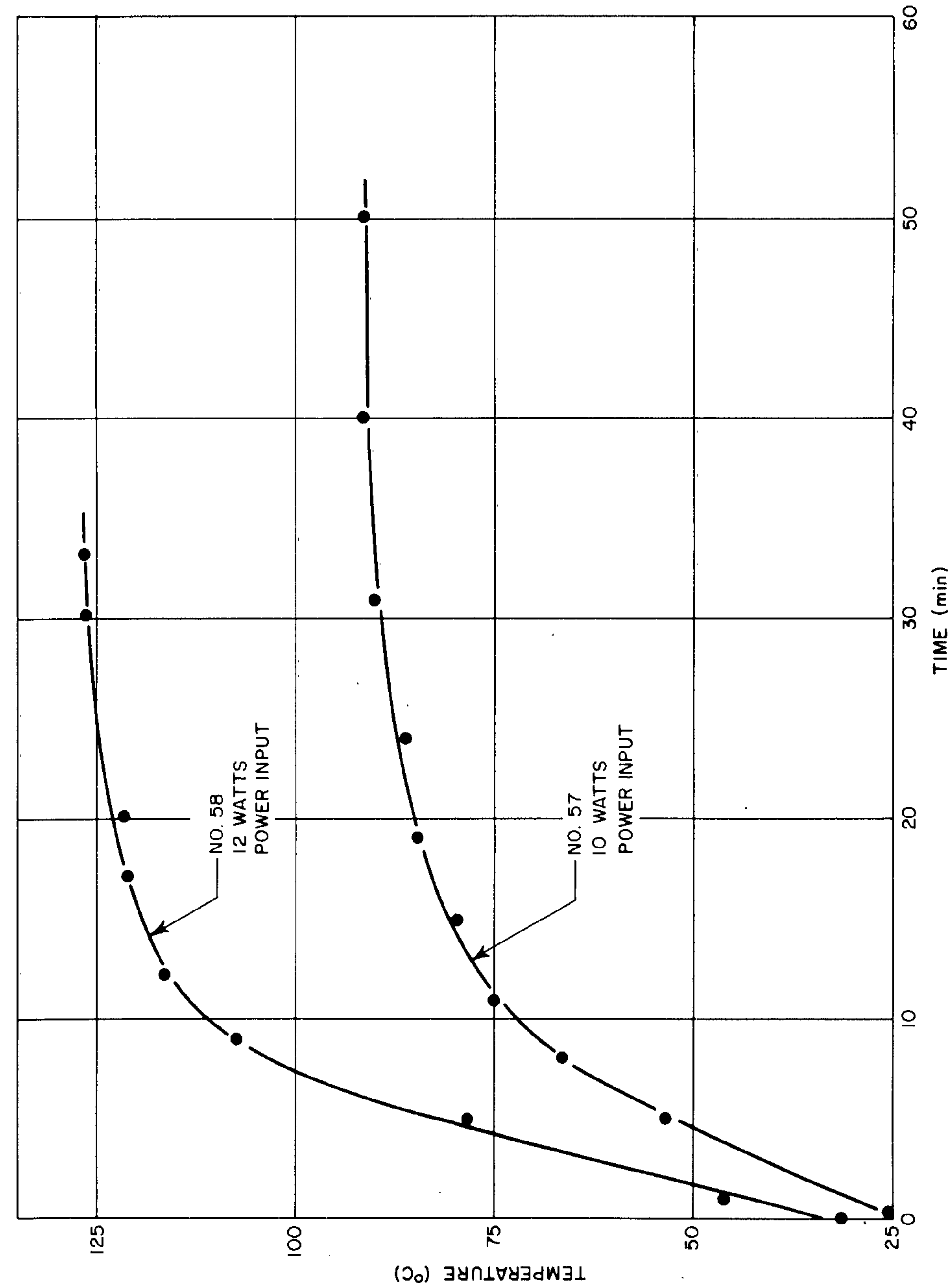


FIG. 1-1. TEMPERATURE RISE OF PROTOTYPE LBT'S AT 250 MC

1.1.4 Attempts to Determine Loss and Temperature Rise at Low Frequency

Results obtained last month at low frequency were done with input power limited to values of less than a half watt. Since both Weston and the Naval Weapons Laboratory had hoped for data at higher power levels we considered reactivating an old transmitter.

The BC 191 transmitter covers a range of 200 Kc to 12 Mc by use of several plug-in tuning units. For our tests we would require the 200 - 800 Kc unit, which was found to be modified so as to be unusable. Upon investigating the nature of the modifications, we decided it would be more expedient to order a new tuning unit from a local supplier. Because of the anticipated delay in delivery it was decided that these tests would not be done on the prototype LBT's under this contract.

1.2 Evaluation of Tantalum Capacitors

On recommendation of the Naval Weapons Laboratory we have begun an investigation of the loss characteristics of a tantalum capacitor. The unit chosen for this analysis is a commercially available feed-through capacitor which is used by the Naval Air Development Center in an RF filter design, presumably because of its lossy nature. Initial measurements in a matched attenuation system indicated that the capacitor may have relatively high loss at broadcast frequencies.

We have fitted ten of these capacitors into brass sleeves, to accommodate their insertion into a universal sample holder. To insure intimate contact for both mechanical and electrical integrity the units are held by use of a film of silver-filled epoxy compound. The assembly is shown schematically in Figure 1-2.

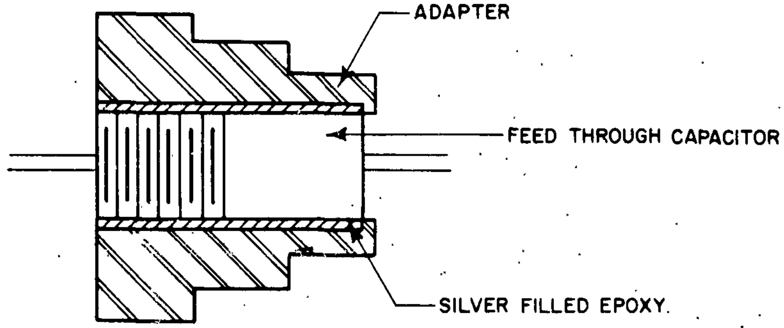


FIG. I-2. UNIVERSAL SAMPLE HOLDER ADAPTER TO ACCOMMODATE TANTALUM CAPACITOR

It is intended that these units be evaluated for worst-case attenuation at 0.5, 1, 5, and 10 Mc. This requires four measurements of input impedance; with output both open and short circuit, and in each direction. Actually three measurements are all that are required, but a fourth is made to check for possible error. These data are then fed into a high speed computer which quickly provides the solution to an otherwise long and tedious calculation.

Following this evaluation of these capacitors, they will be reevaluated in a fixture that will permit salt water to be interposed between the capacitor's outer coaxial conductor and the coaxial line's outer conductor. The design of this mount is in process.

2. CONTINUATION OF SLOTTED LINE VOLTAGE PROBE MEASUREMENTS AT 1 Gc

Voltage min-max power measurements of disk resistor terminations were discussed in a previous report (P-B1980-5). In these experiments we positioned a slotted line at two different locations in a matched system of approximately 120 centimeters total length. We were thereby able to obtain three net power measurements separated a half wave length apart for each of the two locations of the slotted line.

When the resulting data was plotted, a marked discontinuity was observed in the curve relating net power and distance from the load. This was totally unexpected since a discontinuity was inconsistent with the assumption of uniform line loss upon which the experiment was based. These results, therefore, were thought to be caused by a "lumped" series element, most probably a faulty connector or damaged movable contacts in the adjustable line which was interchanged with the slotted line.

We had intended repeat experiments in which, by using other sections of line, we would eliminate the faulty component and obtain a smooth net power curve. When we were in a position to continue this work a new problem unfolded. We found that direct RF radiation from the power source was affecting the instrumentation circuits. The experiments planned were therefore repeated, for expediency, in a simplified manner.

2.1 The Problem of Direct Radiation Into Instrumentation

Our attempts to repeat the slotted line experiments were made with the HERO generator housed in a metal enclosure together with all other equipment necessary for the tests. The dc microvoltmeter used to measure the crystal probe voltage in these experiments was observed to change its reading erratically seemingly related to movements in the enclosure. It was reasoned that this was caused by direct radiation of RF into the instrument through its case. The leakage of radiation from the transmitter cabinet was blamed.

Power density measurements were made in the vicinity of the transmitter. A maximum density of 2 milliwatts per square centimeter was observed directly in front of the transmitter, near the location of the magnetron. This density was lowered by a factor of ten when additional shielding was installed around the cathode area of the magnetron. The transmitter output for these tests was about 125 watts into a dissipative load. The radiation should have been negligible under these conditions; however, the interference with the instrumentation was still severe. It was impossible, therefore, to conduct the particular tests exactly as planned.

We concluded that the metal enclosure, acting as a reflecting cavity, caused reinforcement of leakage radiation at the location of the sensitive instrumentation. Faced with the problem of making the planned tests in the presence of the radiation we devised a new approach.

2.2 Net Power Measurements with Slotted Line and a 0.5 ohm Termination

Despite the pickup of RF radiation, the slotted line experiments were repeated with a 0.5 ohm dish resistor termination at frequencies of 0.98 and 1.13 gigacycles. These particular frequencies were used instead of 1 Gc for reasons which will be explained. The original tests were made in a matched system, 120 centimeters long. A special, short adjustable line was substituted for the assumed defective line initially used. The use of this line and a lower frequency of 0.98 Gc allowed the matched system to be shortened to approximately 90 centimeters. The need for moving the slotted line section was thus diminished, since measurements could now be made over an appreciable part of the shorter matched system.

In the voltage min-max technique net power is obtained by multiplying the voltage at a maximum by the voltage at a minimum and dividing this product by the characteristic impedance of the line. Expressed in equation,

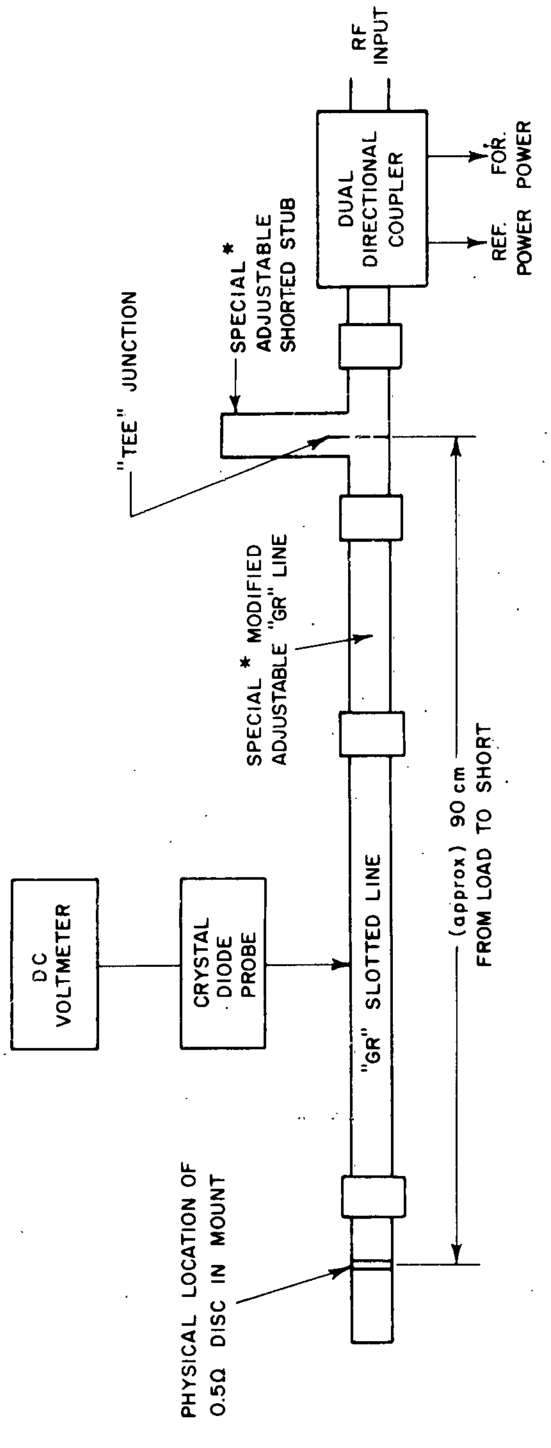
$$P_n = \frac{V_{max} \times V_{min}}{R_o}$$

With moderate system input power (0.135 watts) and with the large standing wave ratio produced by a 0.5 ohm termination, the probe voltage at the minimum will be in the order of millivolts when usual probe depths are used. To cancel the effect of direct radiation, which was most pronounced at the minimum, we increased the probe penetration to obtain a voltage in the vicinity of half a volt for these measurements. The probe was returned to a normal depth for the readings of maxima. This technique complicated the procedure, because separate calibrations with the calorimeter are required for the two probe depths. However, interesting possibilities for using a specially constructed probe calibrated in terms of depth of penetration are suggested by these experiments.

Figure 2-1 is a block diagram of the setup employed for the experiment at 0.98 Gc. With the adjustable line shown in this diagram removed from the system, a second experiment was made in which matching was accomplished by adjusting the frequency and the shorted stub. The length of matching system was then 76 centimeters, requiring a frequency of 1.13 Gc.

The data from these two tests are given in Table 2-1. The probe voltmeter readings have been converted to true volts by means of separate calibration curves made for the two probe depths. Net power and VSWR at various measured distances from the load have been calculated.

Figure 2-2 shows curves of net power versus distance from the load. Examination of the 0.98 Gc curve discloses that the four measured points of net power fall in a substantially straight line, thus suggesting a uniform drop in power throughout the length of the system. However, the measured net power at the input of the system is out of line and suggests that the curve takes a sharp upswing as shown by the dotted line. Once again, the possibility of a lumped series loss in the line is indicated.



*NOTE

THE ADJUSTABLE "GR" LINE HAS BEEN MODIFIED TO HAVE A MINIMUM INSERTION LENGTH OF APPROXIMATELY 13 cm
THE SPECIAL SHORTED STUB WAS MADE IN OUR LABORATORY AND IN THE ABOVE SET UP HAS BEEN ADJUSTED TO CREATE A SHORT ONLY A FRACTION OF A cm FROM THE "TEE" JUNCTION

FIG. 2-1. EQUIPMENT ARRANGEMENT FOR VOLTAGE MIN-MAX POWER MEASUREMENT

Table 2-1

VOLTAGE MIN-MAX PROBE DATA
(0.5 ohm Load @ 0.98 and 1.13 Gc)

Frequency Gc	Distance from load to Probe (Centimeters)	Probe Voltmeter Reading (volts)	True Volts (From Calibration Curve)	Net Power Toward Load $= \frac{V_{max} \times V_{min}}{50}$ (watts)	VSWR = $\frac{V_{max}}{V_{min}}$	System Input Power (watts)
.98	14.9	0.0635	0.24	0.0649	56.4	0.135
.98	22.5	0.505	13.54	--	--	0.135
.98	30.3	0.076	0.27	0.0729	50.0	0.135
.98	38.0	0.500	13.45	--	--	0.135
.98	45.7	0.085	0.305	0.0816	43.9	0.135
.98	53.4	0.495	13.30	--	--	0.135
.98	61.0	0.093	0.33	0.0878	40.3	0.135
1.13	12.4	0.0645	0.272	0.0826	55.8	0.135
1.13	18.9	0.617	15.18	--	--	0.135
1.13	25.4	0.0775	0.295	0.0893	51.34	0.135
1.13	31.9	0.615	15.1	--	--	0.135
1.13	38.4	0.0845	0.310	0.0930	48.38	0.135
1.13	44.9	0.605	14.9	--	--	0.135
1.13	51.4	0.0937	0.329	0.0977	45.13	0.135
1.13	57.8	0.60	14.8	--	--	0.135

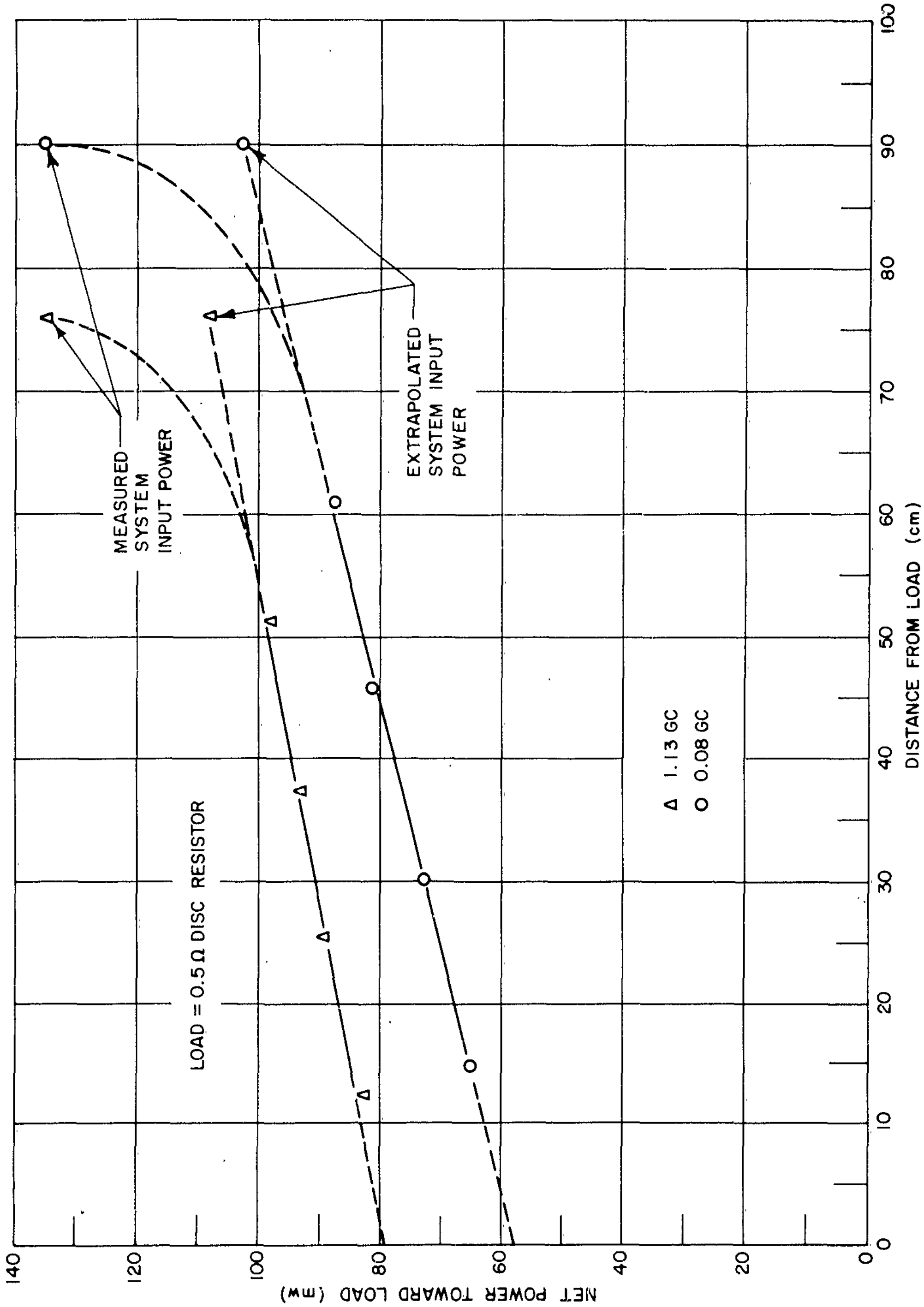


FIG. 2-2. NET POWER TOWARD LOAD VERSUS DISTANCE FROM LOAD

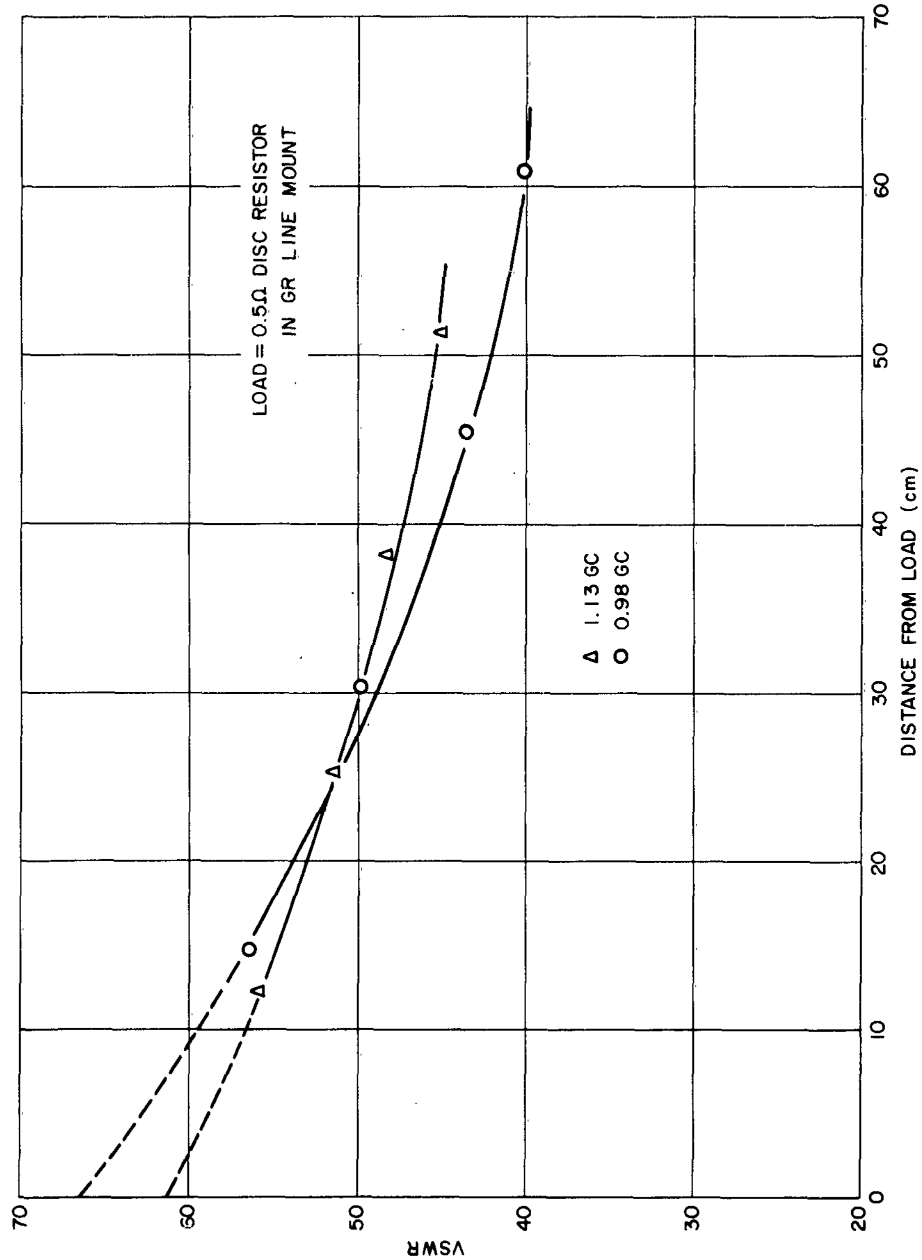


FIG.2-3. VSWR VERSUS DISTANCE FROM LOAD

However, the test at 1.13 Gc was made to eliminate the assumed faulty adjustable line from the system altogether, and reference to Figure 2-2 shows that the second curve follows the same basic pattern as the first. This would indicate that the adjustable line was not at fault. In Figure 2-3 the plot of VSWR versus distance from the load gives no additional clues.

These tests have neither proved nor disproved the points that we originally set out to make. We are, however, confident that this basic method for predicting the power arriving at the input of an arbitrary load is sound. A little more work in certain areas is still necessary before we have unquestionable proof that this is so. Our major concern is that the decrease in power as we move from the input to the load should be almost linear, but our data do not fully support this conjecture. Moreover previous data indicate a high loss element located around the mid point of the system; the recent data move this point to the input. A reasonable explanation should emerge from more rigorous analyses.

ACKNOWLEDGEMENTS

Credit is due Charles Stonecypher for the evaluation of the LBT's discussed in Section 1, and to J. P. Warren for his efforts to collect and present the data given in Section 2.

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